I. C. 6514

SEPTEMBER, 1931

DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
SCOTT TURNER, DIRECTOR

INFORMATION CIRCULAR

MINING METHODS OF THE MOLYBDENUM CORPORATION OF AMERICA AT QUESTA, N. MEX.

RECEIVED
OCT 15 1
O. S. U. LIBR

BY

J. B. CARMAN

I.C.6514.
September, 1931.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

MINING METHODS OF THE MOLYBDENUM CORPORATION OF AMERICA AT QUESTA, NEW MEXICO[1]

By J. B. Carman[2]

INTRODUCTION

This paper, describing the mining practices and methods at the mine of the Molybdenum Corporation of America, is one of a series of similar papers on mining methods in the various mines of the United States being prepared by the Bureau of Mines.

The mine of the Molybdenum Corporation of America is in the Red River mining district, Taos County, northern New Mexico (fig. 1). The mill and camp are in the valley of Red River, about 7 miles east of the town of Questa; the mine is 1¼ miles away, in Sulphur Gulch, a tributary of Red River. The mine is about 600 feet higher than the mill, at an altitude of about 8,700 feet. The climate is cold in winter, but does not interfere seriously with continuous operation. The mine normally produces about 40 tons of sulphide molybdenum ore per day, which is concentrated at the local mill and shipped to the plant of the Molybdenum Corporation at Washington, Pa.; there it is made into either ferromolybdenum or "molyte" (calcium molybdate), for use in alloys. The ore is mined from narrow, irregular veins by the cut-and-fill method. About 65 men are normally employed underground and on the surface at the mine.

The assistance of C. H. Johnson, assistant mining engineer of the United States Bureau of Mines station at Tucson, Ariz., in arranging the material in this paper for publication is acknowledged.

HISTORY OF PROPERTY

This property was first recognized as a potential producer of molybdenum in 1916 or 1917, when the metal was at a high premium. The story is told that the outcrop had been known of locally for a long time, but the molybdenite was mistaken for graphite, and the mineral had actually been mixed with grease and used as a lubricant by farmers nearby. Some claims were located during the war. The R. & S. Molybdenum Mines Co. was organized in November, 1918, by two men from Cripple Creek, Colo., and some ore produced which was milled at a gold mill on Red River about 5 miles above the mine. The Molybdenum Corporation of America was incorporated in 1920; in the same year it acquired this property, and operations were continued on a small scale until the market vanished in the general depression of 1921. However, a small amount of development work was continued, and in 1923 the construction of the present mill and camp site was started. The mill began operation on November 1, 1923, since that time the mine has been worked continuously.

---

[1] The Bureau of Mines will welcome reprinting of this article, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6514."

[2] Manager, Molybdenum Corporation of America, Questa, New Mexico, and one of the Consulting engineers, U. S. Bureau of Mines.

The production of the mine previous to the starting of the mill was about 250,000 pounds of molybdenum sulphide; including that amount, the production to January 1, 1931, has been approximately 5,000,000 pounds of molybdenum sulphide in the form of concentrates.

GEOLOGY

The rock in which the ore occurs is described as a soda-potash alaskite porphyry.[3] This is intrusive into a dark-gray granodiorite porphyry. The alaskite and the granodiorite are overlain by volcanic tuffs and flows, which are not present, however, in the immediate vicinity of the workings.

The mineralized veins are distributed very irregularly in east-west fracture zones which are sometimes several hundred feet wide. The veins consist of groups or sets of closely spaced, branching and interfingering fractures that are often separated from other vein systems in the same shear zone by many feet of barren rock. The fracture zones are much longer, as well as wider, than the mineralized veins found within them.

A system of north-south fractures offsets the veins in many places. These fault zones are entirely barren.

The only mineral of economic value is molybdenite (MoS_2), which occurs as a fissure filling in the east-west system of veins. The most important gangue mineral is quartz, with some pyrite, and minor amounts of biotite, fluorite, rhodochrosite, and calcite. The space between the small branching quartz-sulphide veins is occupied by altered, sericitized country rock; the vein filling actually comprises only a small proportion of the ground broken in mining.

No veins of economic value have been found in the granodiorite, and mineralization in this rock is limited to small stringers branching from veins on the contact between the alaskite and the granodiorite; such stringers never extend more than a few feet away from the contact.

The oxidation of the veins is very shallow, rarely extending more than a few feet below the surface, and generally some sulphide persists even at the surface. The broken ore in stopes does not oxidize rapidly enough on standing to injure it for milling treatment. The mine waters are alkaline, whereas if oxidation of the sulphides were taking place to any considerable extent, acid waters would be in evidence.

PHYSICAL CHARACTERISTICS OF ORE AND COUNTRY ROCK

The alaskite and the diorite, as well as the vein material, are very easy to drill and break. Development workings in the country rock do not require timbering. Drifts along the veins usually stand well and normally are not timbered before the start of stoping; about one-quarter of the drift footage is in heavily broken ground which requires support. Stulls are used for temporary support in some stopes, particularly the more flat-dipping

---

[3] Larsen, E. D., and Ross, C. S., The R. & S. Molypdenum Mine: Econ. Geol., vol. 15, November, 1920, pp. 567-573.

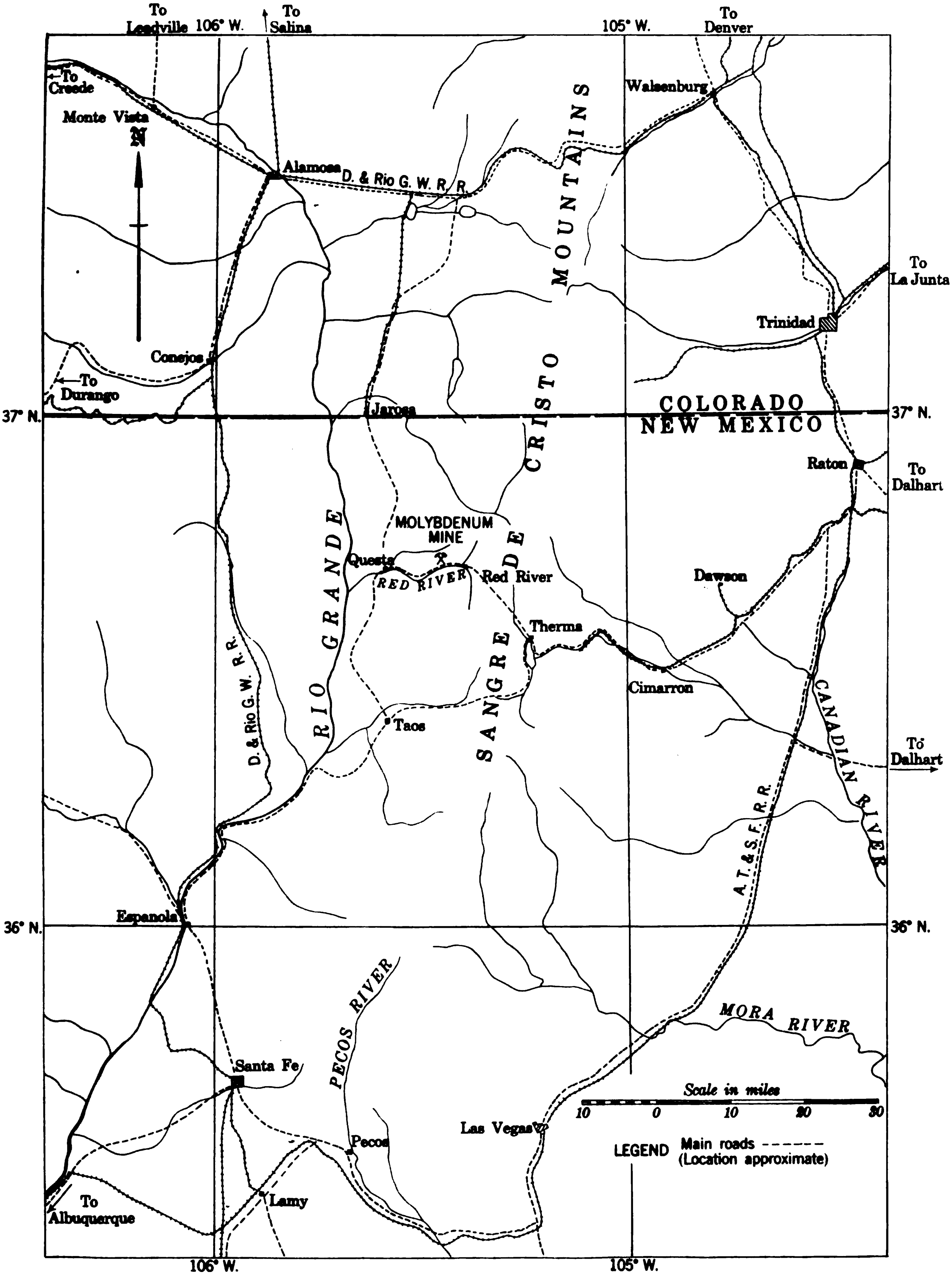

Figure 1.—Map showing location of mine of Molybdenum Corporation of America

ones; a few stopes have been worked out without support of any kind. The ground near the veins is not heavy in the sense that it "squeezes"; the chief difficulty in mining is caused by the often shattered and blocky nature of the ground where transverse slips have cut the main fissure. The granodiorite appears to be more fractured than the later intrusive. Sometimes the veins are largely gouge-filled, which increases the mining cost. The molybdenite itself is very friable, and large amounts of fines are produced in blasting unless it is done carefully.

Although the mechanical characteristics of the ore and country rocks offer no great obstacles to mining, the small size and irregular distribution of the ore bodies make them difficult to find and expensive to explore and develop. The largest continuous vein developed to date is about 1,400 feet long and 400 feet along the dip; the veins are commonly 200 to 500 feet long, with a length down the dip about one-third their horizontal length. The largest single stope extends about 240 feet along the strike and 170 feet along the dip; the average stope is probably not over half this size.

The dip of the veins ranges from 20 to 90° from the horizontal, and averages about 60°; it may change greatly or even reverse with depth.

The width of mineralization ranges from a fraction of an inch to 6 feet; sometimes the walls of the vein may be 10 feet apart, but in such cases the ore is confined to thin streaks close to the walls, with country rock between. For the whole mine the average width of material taken as ore is probably between 12 and 18 inches. Some relatively large stopes have been worked on veins averaging 4 feet in thickness. Ore of exceptional purity can be stoped profitably when as thin as 2 inches, and is commonly mined from veins not over 6 inches thick.

Transverse faulting has offset the ore so frequently that exploration is made very difficult, although the displacement is seldom more than 12 to 15 feet. The faulting and mineralization appear to have taken place together, although at more than one period. As the direction and extent of displacement are not at all uniform, it is impossible to predict in a given case where a lost vein will be found, or whether the ore ever extended any farther.

The ore shipped to the mill has a specific gravity of 2.56, which is equivalent to 12.5 cubic feet per ton in place, or about 19 cubic feet per ton, broken.

PROSPECTING AND EXPLORATION

The outcrops of the veins, being softer than the country rock, do not protrude above the surface. Where a vein outcrop is bare, however, as on a cliff or on the top of a sharp ridge, it is conspicuous because of the bright canary-yellow color of the molybdite, the usual oxidation product of molybdenite. The original prospecting of the property started by drifting on such outcrops, or crosscutting to them at lower elevations and then drifting along the vein. Following the exploration of one vein, crosscuts are usually run into the country rock in one or both directions to discover parallel veins.

Underground prospecting is done more or less blindly, although certain factors are recognized as guides. It is believed that economically important ore bodies will be found only near the margins of the alaskite porphyry. It has been noted that the ore is most abundant where mineralized fractures are intersected by fissures of nearly the same strike but usually different dip. Rolls in the fault planes are often found to contain good ore. The best ore is usually found near the edge of an ore shoot, where the lens of sulphide is thick enough to be mined cheaply, yet not thick enough to include streaks of waste. A "fresh" appearance of the molybdenite is encouraging, and a stringer of such material is followed for a considerable distance, especially after commercial ore has been found in one or more places along it.

Stoping work is forced to carry part of the burden of prospecting, and at times is prosecuted in veins which are too narrow to pay, because of the desirability of following all mineralization to its end. Raising in ore is usually not done ahead of stoping, although in new country, a raise is sometimes run to determine the vertical extent of minable ore.

Because of the irregular dip of the veins, as well as the patchy distribution of the ore shoots, the downward projection of ore from level to level is not always successful.

No diamond drilling or long hole drilling is done because these methods of prospecting are not suitable to the ore occurrence; the ore shoots are so scattered that negative results from drilling would be untrustworthy and any ore found would have to be checked by later development. Moreover, the difference in cost between the footage of drilling that could be carried economically by the operation, and any similar amount of drifting, is not sufficiently large to make diamond drilling attractive. In the stopes, however, if there is reason to suspect that a branch vein exists close to one or another of the apparent walls, stoper holes are drilled into the walls and the cuttings inspected for ore.

Geophysical prospecting was done on the property in the fall of 1927.[4] Only a small portion of the indications have been tested. Good ore has been found in some places where it was strongly indicated by the survey. In one case good ore was found, not exactly at the indicated spot, but within 40 or 50 feet of it. In a few places ore has not yet been found, but in no such case has the possibility of ore been disproved. It is felt that the survey was decidedly a worthwhile investment.

SAMPLING AND ESTIMATION

The grade of ore is estimated with fair accuracy by inspection. Sampling of ore in place is done only in a few cases to check visual inspection as a guide to stoping, or rarely where the material is low-grade and an assay is desired to distinguish ore from waste. No samples of broken ore are taken at the mine. The ore from each stope, which is kept separate for purposes of contract payment, is grab-sampled as each truck load is weighed at the mill. This grab sampling is checked by an automatic sampler in the mill and is found to be sufficiently consistent for the purpose of mine operation.

Estimates of ore in a given vein are based on the appearance of the vein in drifts or stopes, and on past experience with similar-appearing veins in nearby parts of the mine. Such estimates of "probable ore" are not often correct as applied to short distances along a vein, but when applied to lengths of two or three hundred feet they have proved to be very

---

[4] Sundberg, Karl, and Nordstrom, Allan, Electrical Prospecting for Molybdenite at Questa, New Mexico: Geophysical Prospecting, 1929, Am. Inst. Min. and Met. Eng., pp. 125-137.

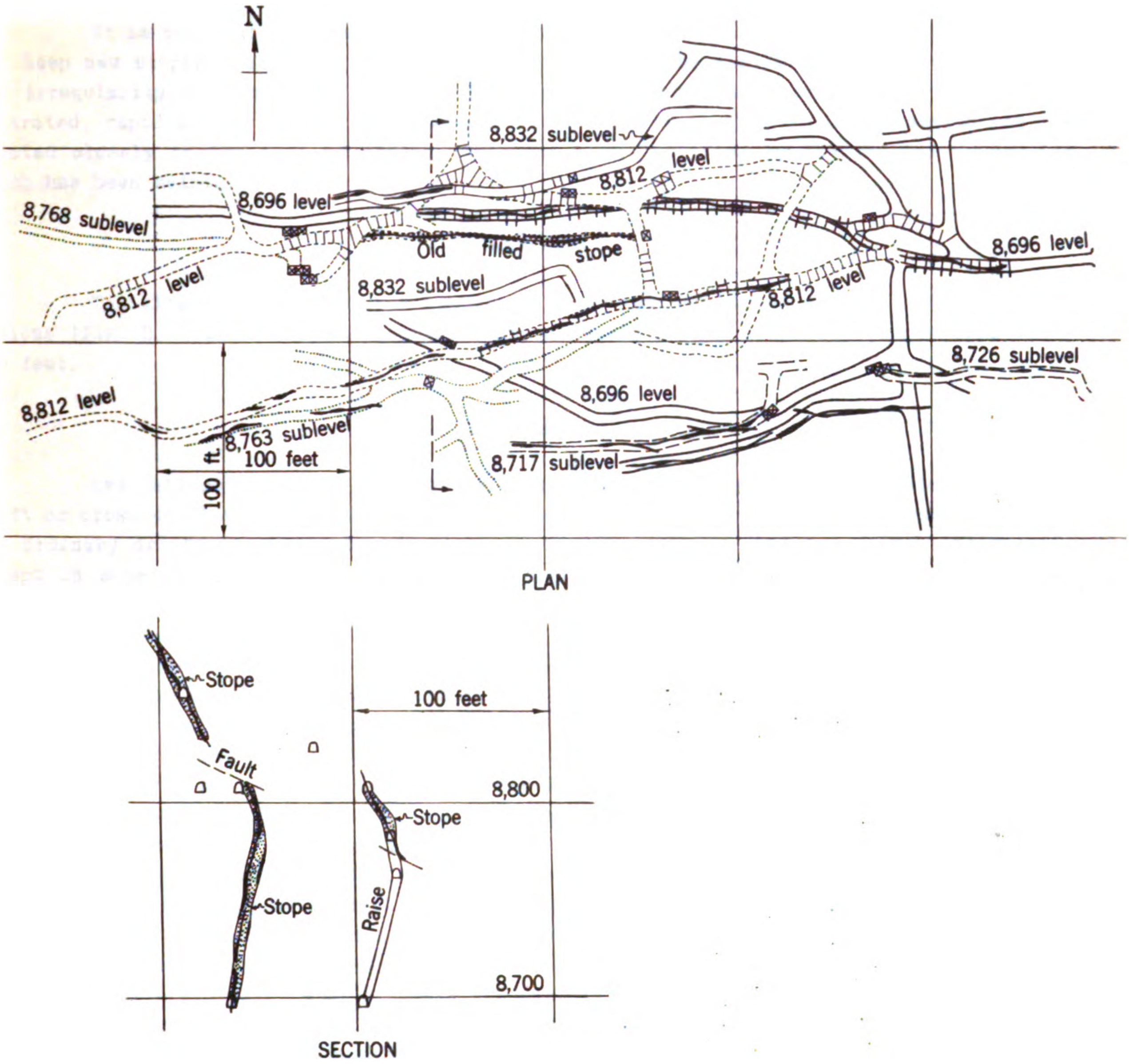

Figure 2.—Plan and section of portion of mine, showing method of development

close to actual extraction. The assumption is made, and with apparent justification, that veins of similar appearance, as regards thickness and character of mineralization, and located in geologically similar position, will produce amounts of ore in proportion to their areas - that is, length times width in the plane of the vein.

It is necessary to keep prospecting work spread out, in order to develop new areas and keep new stopes starting. Furthermore, stoping must be similarly spread out, to avoid the irregularity of production which would result if production were obtained by the concentrated, rapid mining of only a few stopes at a time. Both of these requirements are reflected closely in the cost of mining, but have been justified by the regular production which has been maintained.

DEVELOPMENT

The mine is developed by a number of adits and tunnels at several different elevations (fig. 2). The vertical interval between levels on the same vein ranges from 40 to 100 feet.

Drifting

One untimbered 5 by 7 foot adit several hundred feet long is larger than the usual drift or crosscut, having been driven with a view to its future use as a main haulage level. The ordinary drifts or crosscuts are 4½ by 6½ feet in section, and are driven untimbered, except in some places along the veins or in badly fissured country rock. The amount of drift and crosscut which must be timbered when driven because of heavy ground conditions is about 10 per cent of the total .

Machine drilling is done with a light drifter-type machine. Mounted jackhammers have been used, but were not adapted to the work; repair costs were higher, and poorer rounds were drilled. Seven-eighth-inch, hollow-hexagon, carbon steel is used with the drifters. The bit is the ordinary cross bit with a double 5° and 14° taper. Starter bits are 2¼ inches in diameter with gage changes of ⅛ inch and length changes of 18 inches. A few 135-pound drifters are used which were salvaged from another property. These take 1-inch, hollow-hexagon steel; bits for this steel are the same as described above. Line oilers are used with all machine drills. The machine-drill round ordinarily used in drifting is a 7 to 8 hole toe-cut round, drilled from a 3-inch horizontal bar over the muck pile. When properly drilled it breaks an average of 4 feet. The holes are loaded with 1 by 8 inch, 40-per cent strength gelatin dynamite; 4 or 5 sticks are used in the cut holes, 4 in the lifters, and 3 in the breast or back holes, or a total of 26 or 27 sticks per round. The explosive is detonated with No. 6 or 7 caps and fuse. A 50-per cent strength bulk powder in 1 by 8 inch cartridges, running about 50 per cent more sticks per box than the regular gelatin powder, was tried; it was found to produce marked economies in operation, because the miners used no more sticks than formerly and often actually less. However, it deteriorated very rapidly because of the lack of perfectly dry storage places at all of the scattered workings, and its use had to be discontinued. No stemming is used by the contractors, either on development or stope work.

Shoveling is all done by hand into 12 or 14 cubic foot cars; the broken material is trammed by hand to the surface or an ore pass.

Drift sets are stood on 5½-foot centers. Posts are of 7-inch and caps of 8-inch round timber; collar braces are of 3-inch round and lagging of 3-inch split material. The poosts are 6 feet, 2 inches long, and are stood 4 feet apart at the top and 4 feet 4 inches at the bottom. The timber is mostly native Douglas fir and a little white spruce. It is being cut at present from burned-ovor areas, is well seasoned and gives satisfactory service. No preservative is used.

A drift crew consists of a miner and a mucker, working on the same shift. Development work may be done on either day or night shift, or both.

All development work and stoping are done on contract. Conditions vary greatly, and most of the details of drifting practice are not standardized, but are varied according to the ideas of the contractors.

A considerable amount of drifting in soft ground is done with hand drilling. In this case the work is organized differently. Each man works alone, breaking, mucking, and tramming. Drill steel is ⅞-inch octagon, sharpened to the regular chisel bit. Starter bits are 1¼ inches wide, and four gage changes are provided of 1/16-inch each. The longest steel is about 4 feet long. Four-pound single-jack hammers are used. Hand-drilled rounds average less than 2½ feet in depth, and have no standard form; the miner places his holes and points them to take every possible advantage of slips and joints in the ground. The average hand-run drift is less regular in shape than the machine drift, and is smaller, being about 4 by 6 feet in section. Occasionally for prospect purposes a hand drift will be run barely large enough to work a wheelbarrow, but usually regular track is laid and the broken rock trammed in cars. Seven-eights by eight inch powder is used for blasting. The economy in the use of powder resulting from the better placing of holes is shown clearly in Tables 1 and 2 at the end of this paper.

The rate of advance by hand drilling is slower than with machine drilling. However, two expert men, working two separate faces on the same contract, made an advance of 124 feet in 52 working days, or an average of 1.2 feet per man-shift. The drifts in this case were 4 by 6 feet in section. The men shoveled and trammed their own muck a distance of 600 feet.

Raising

About a fifth of the total development footage consists of raising. Raises are of two general types - cribbed or stulled, and may have one or two compartments. They are almost always inclined.

Hand drilling in raises is similar to that described under drifting.

Machine drilling in raises is done usually with 89-pound hand-rotated stopers, using 1-inch solid cruciform steel. This steel is sharpened with the same bits, gage, and length changes as the drifter steel. A few 110-pound wet self-rotated drills are used for raises of more than usual height, such as, for example, a 150-foot, three-compartment raise which was driven for a manway, air raise, and ore pass. These machines use 1-inch hollow hexagon steel. Center V-cuts with eight holes are used in two-compartment raises, and end cuts in single compartment raises. Blasting practice is the same as for drifts.

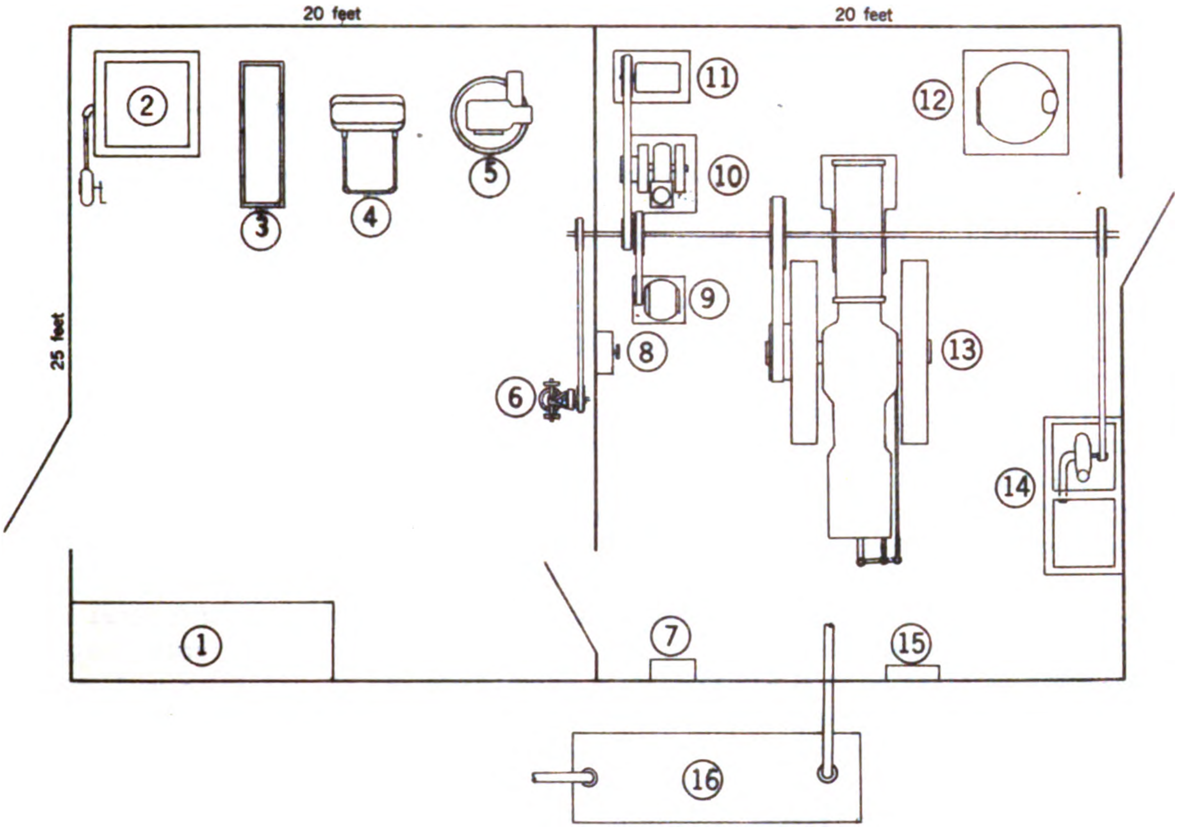

Figure 3.– Mine blacksmith shop and compressor house

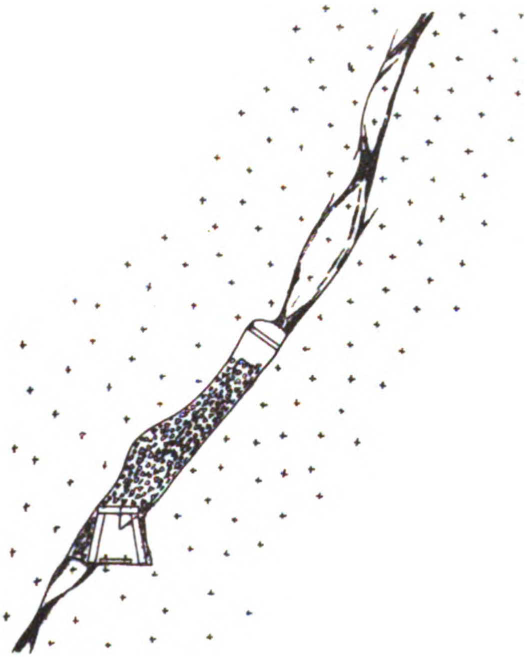

Figure 4.– Section through typical stope

A two-compartment stulled raise is ordinarily timbered with a single row of 7-inch round stulls placed from foot to hanging wall at 5-foot centers along the center line of the raise. The stulls are lagged on the chute side with half-round 3-inch lagging. Each compartment is 3 by 3 feet square.

Cribbing for raises is made of about 6-inch round timber, dapped at the ends and center to give 2 to 4 inch spacing between cribbing. The center cribbing in a 2-compartment raise is lined on the chute side with plank or split lagging to prevent rock from working through into the manway.

COMPRESSED AIR AND STEEL SHARPENING

Air for drilling is furnished by a compressor driven by a 17 by 19 257 r.p.m. 110-hp. full Diesel engine. The compressor is 2-stage, having a 16½ by 13½ inch differential piston connected tandem with the engine piston. The compressor has a sea-level rating of 600 cubic feet of free air per minute, but is only 75-per cent efficient at this elevation; it delivers 450 cubic feet of free air per minute at 90 pounds per square inch of pressure. The compressor serves, at a maximum, five drifter machines and five stopers. The stope drilling is intermittent, so that all machines are seldom working together. The pressure at the drills is about 80 pounds per square inch. The compressor discharges into a 4 by 10 foot receiver from which the air is taken to the portals of the main adits through a 4-inch line 2,200 feet long. The underground air lines are of 2-inch pipe. Two semi-Diesel 9 by 14 by 9 inch compressors, which formerly supplied the mine air, are kept in working order as stand-bys. These together are capable of delivering about 350 cubic feet per minute. The mine air line drains readily and the air passing through it becomes colder than the underground mine temperature, so that no trouble is experienced with freezing of air lines. Two additional receivers of about the same size as that at the main compressor are connected into the air line, one at the reserve compressors, and one in an intermediate position.

Figure 3 and the following list show the equipment and layout of the main compressor and blacksmith shop.

1. Work bench,
2. Coal forge,
3. Quenching tank,
4. Oil forge,
5. Drill sharpener,
6. Grinding wheels,
7. Recording pressure gage,
8. Rheostat and voltmeter,
9. D. C. generator, 1.5 kw., 115 v., 13 amp., 1,900 r.p.m.,
10. Water-cooled gasoline engine, 6 hp., 450 r.p.m.,
11. Starting-air compressor, 3½ by 3½, 475 r.p.m., 250 pounds pressure,
12. Coal heating stove,
13. Oil-engine-driven compressor,
14. Cooling water sump and return pump,
15. Lubricating oil filter,
16. Receiver, 4 by 10 feet.

The Diesel is ordinarily used to pump up the 375-pound starting air tank. However, if this fails to start the engine, the Fairbanks-Morse gasoline engine is used to refill the tank. This is belt-connected to a small 2-stage compressor. The Diesel and gas-engine are connected to the overhead shaft in such a way that they can be used independently as desired. Water from an outside tank above the compressor house runs by gravity through the compressor cylinder jackets and intercooler, thence through the Diesel engine water jacket, and into a small sump in the floor of the compressor room. From that point it may be either run to waste or returned to the supply tank by a 2-inch centrifugal pump, belt driven from the overhead shaft.

Machine steel is sharpened in a compressed-air sharpener; an oil-fired forge is used for heating and tempering. A small coal forge is used for sharpening hand steel; this is connected for blowing by hand or with compressed air. Water for the compressor and shop was developed by driving two short tunnels and building a retaining dam in the bottom of an apparently dry wash above the blacksmith shop. Water for drilling is collected in small sumps in the mine, and is supplied to the machines by portable water tanks.

One man on each shift operates the compressor, sharpens steel repairs drills and hose, and does general blacksmith work.

STOPING

About nine-tenths of the ore mined is extracted by horizontal cut-and-fill stoping and one-tenth by open stoping. The proportion varies slightly from time to time. Usually the ground requires the support given by filling. Other factors which may favor the cut-and-fill method are (1) the frequent necessity of breaking much more than the width of the ore to provide working room, in which case the resulting waste is most cheaply disposed of as stope fill and (2) the occasional very long tramming distances from stope to surface ore bin, which causes the contractors to do practically all of their sorting in the stope, the rejected waste then being used as fill. Open stoping is used where conditions permit, chiefly because it insures complete recovery of ore; particularly where the walls are of relatively hard, firm rock, there is considerable shattering of the ore in blasting, with increased danger of loss of fine material in the fill. The contract price of stoping is the same for filled and open stopes.

In both methods the ground is broken by overhand mining. In only one or two places the walls and ore have proved so soft and weak that overhand stoping was impossible. In these cases the ore was broken by breast stoping, the back supported by horizontal stulls and lagging, and the stoped ground filled closely.

Cut-and-fill stoping

A cut-and-fill stope is started by taking a cut from the back of the drift and placing drift sets and lagging, and then building chutes. In this work an effort is usually made to avoid loading much ore or waste by hand, to avoid blasting directly down on unprotected timbering, and to place the waste fill as soon as possible in order to keep within working distance of the back. In some places, a 5 or 6 foot cut is taken from the back of the drift for a distance of perhaps two sets. This is loaded by hand into cars, and sets stood and lagged over. The next round is drilled and blasted so as to throw most of the ore over onto this timbering, where it can be sorted, and the ore dropped through the lagging into cars. Another set is then stood and the process repeated. In this way little hand loading is necessary and a fair covering of waste is left to protect the timbering when taking the next cut from the back. Another method of procedure is to break down a short 2 or 3 foot round from the entire length of the drift back to be included in the stope, then, working from on top of this broken material, drill a second round. Before shooting this, however, the first round is mucked out and timber stood. Then the second row is shot a few holes at a time and the broken ore sorted and dropped into cars below. The timbering under a stope is usually standard drift timber with single lagging overhead. In narrow stopes where the walls are good, stulls are occasionally used, or, perhaps, half sets, in which the hanging-wall end of the cap is supported on a post and the other end by a niche on the footwall.

Chutes are next built at 50-foot intervals, with manways at every other one. If a stope is less than 50 feet long, only one chute may be required. The loading chutes are of 2-inch plank, with double-plank control gates held in cleats. The ore chutes and manways are carried up by cribbing or by setting stulls from wall to wall and lacing them on the outside with split lagging. In 2-compartment raises the chute compartment is lined with plank on the manway side to prevent fine ore from running between the cribbing or lagging. The single compartment chutes are usually about 3 feet square inside; the cribbing may be made of timber as small as 5 inches in diameter. The tonnage handled through stope chutes is very small and the ore is not hard or abrasive. Consequently the lightest construction that will safely hold the weight of the fill is permissible and economical. As all ore is worked over by hand in the stopes, no grizzlies are used over the tops of the raises.

Although ventilation or prospect raises are sometimes driven from level to level in ore and later made use of in stoping or may be driven for these purposes after stoping has started, no raises are driven from level to level for purely stoping purposes, such as travel ways or for lowering supplies into stopes. This has been done in the past, but it was found very difficult or impossible to break the ore cleanly in a raise face, and the cost of the raises seemed excessive for the advantage gained.

Drilling and blasting account for only a small part of the labor in stopes at this mine. The ground is broken by stoper holes drilled almost straight into the back. Only a short length of back is drilled at a time, and the depth is seldom over 3 feet; where hand drilling is done, even less depths are broken. An effort is made to employ hand drilling in the stopes in soft ground, as recovery of the ore is cleaner and more complete. Hand drillers give much more regard to the condition of the ore or walls or the presence of cracks or slips; moreover, much less powder is used. Machine drilling is done with 89-pound hand-rotated stopers, using the same steel as described under "Development." Blasting is done with 40-per cent strength gelatin dynamite and No. 6 caps and fuse. Shooting is usually done at the end of the shift, but if ventilation is good it may be done at any time.

Various methods of breaking the ore are used, depending on the ore occurrence and the ideas of the foreman and miners. Figure 4 gives a cross section of a typical stope, showing the extreme variation in width of ore and occurrence of included waste. Where the ore is of sufficient width to give working room, and no breaking of the walls is necessary to fill the stope (that is, sufficient fill would be obtained by sorting), then the ore is broken down and the wall left uutouched. If, as more commonly happens, the ore is not wide enough to provide working room, the practice is to break the footwall away from the ore, sort out of this waste such ore as has come down with it, then take down the ore exposed on the hanging wall. This can be done by picking or very light shooting. Shooting holes in the ore streak is objectionable because it tends to pulverize and scatter the ore. If the ore is too loose to stick to the hanging wall it must be brought down with the waste and sorted. If the ore is in streaks along both walls, as often happens, the waste between can sometimes be mined first, and the ore afterward. The ore occurrence is so irregular that stoping practice may have to change almost every round.

Loose parts of the back are temporarily supported by stulls from foot to hanging wall. The contractors are required to cut, handle, and place this timber without extra compensation.

Plank flooring is sometimes laid on the fill before shooting down ore, to prevent the loss of ore in the fill. (It is particularly advisable if the waste fill is composed of coarse material.) This is not the usual practice, however, and the fill is simply leveled, and perhaps covered with a surface of fine waste before blasting. Dry-walls are sometimes built to provide level floors when part of the stope is higher than the rest; this avoids scattering of ore down the slope.

The ore is shoveled by hand into the chutes. If the distance to a chute is greater than usual, wheelbarrows may be used, but this is not necessary for the ordinary 50-foot spacing of chutes. Double handling is usually necessary in any case because of the sorting. In flat stopes some shoveling or scraping may be necessary to move the ore down the chutes, as it will not run on less than a 40° slope.

Stope backs should be kept horizontal. The tendency of the stope contractors is to push the wider and richer faces ahead and slight the narrow parts of the vein. An irregular back leads to operating difficulties and if allowed to become too much so there is the possibility of overlooking and losing good ore. If the ore pinches persistently in one place, that ground is sometimes left in place as a pillar. No known minable ore is left in place, and no pillars are left under or over levels.

Some sorting is almost always done in stopes. It may consist of merely picking out coarse waste, if the ore can be broken clean. Otherwise, the broken material may be shoveled onto an inclined screen of 2 or 1 inch wire mesh, or rarely ½ inch. The size screen used depends on the nature of the material, the idea being to pass most of the ore and exclude as much waste as possible. If much ore occurs in chunks which would not pass through the finer mesh, the 2-inch screen would be used. Even then the oversize would perhaps have to be picked over by hand for large chunks of ore.

If the ground is soft and breaks finely and the ore is scattered so that little volume can be eliminated by sorting or screening, then stope sorting may be omitted, and this work be done at the surface. Rarely the ore can be broken so cleanly and be of such grade that it can be shipped to the mill without any sorting or screening either in the stopes or at the ore bins.

The amount of waste sorted in stopes varies greatly, according to the mining scheme and the ore. Most of the ore receives some additional sorting at the surface, as will be described later; it is estimated that 60 per cent of the material broken as ore is rejected by sorting or screening and left in the stopes and that 10 per cent of the remainder is rejected by sorting at the surface.

Two to four men work in a stope, one or two of whom are contractors. Drilling, sorting, timbering, and mucking may be done indiscriminately by these men as the need arises. They also deliver the ore to the loading bins and sort it there.

Figure 5 shows the general design and construction of a typical sorting bin such as is built at the portal of each important producing adit. The track from the mine runs over the top of the bin, which in the case illustrated has four compartments. With the screen arrangement shown, the bin could care for the output of two contracts. Ore may be dumped directly into one of the unscreened compartments if it does not require sorting. Otherwise it is dumped onto a screen. The oversize slides onto the sorting platform where pieces of ore are picked out by hand and thrown into the adjacent bin. The waste is then shoveled into a car on the waste track and trammed to the dump. The sorting is done by the contractors as part of their stoping contract.

Open Stopes

Open stopes are usually small and are usually in flat dipping veins. The method is often applied to ore which is known to be of slight extent or to ore whose extent is doubtful and where it is desired to explore in this way before installing chutes and regular drift timbering. In the latter case the ore and waste are shot down onto the drift floor and trammed to surface for sorting. When such a small stope opens up it may be timbered or converted to a fill stope. When the ore in a regular filled stope splits, open stoping may be used to follow it for a short distance to avoid the necessity for building chutes and manways up through the fill.

The chief difference between open stoping with stulls on a larger scale and fill stoping is that more stulls may be used and that most of the material broken is removed; some sorting, however, is almost always done in the stopes and the waste gobbed in the bottom of the stope, so that the hanging wall is actually supported by this fill to a conliderable extent. The method of breaking ground is the same as in a filled stope.

TRANSPORTATION

The ore is trammed to the surface and dumped into the bins by the stope crews. The cars on most levels are 12 or 14 cubic foot, box-body, end-dump type, weighing about 700 pounds and holding about 1,500 pounds of ore. The newer cars are provided with roller-bearing cast-iron wheels. They have a step hook to permit swinging and dumping and a lever to release the end door. The 12.3-cubic foot cars are 24 inches by 48 inches inside, 18¾ inches deep, and are 34½ inches high above the rail. On two levels larger cars are used. The long crosscut mentioned under "Development" is equipped with 16-cubic foot, box-body, end-dump cars, fitted with roller-bearing wheels.

Track is of 8-pound steel rail laid to 18-inch gage on 4 to 6 inch ties of round timber slabbed flat on top and bottom. The track in the long crosscut is of 12-pound rail, and this size will be used to replace the present track in one other level where the 8-pound track is proving too light for the 16 cubic foot cars used there.

The hauls from stope to ore bin range from 200 to 1,000 feet, averaging about 800 feet.

Ore from some of the higher and more remote tunnels, comprising about 15 per cent of the total mine output, is transported to the truck-loading bins by burros. This work is contracted to one man who operates a string of one or two dozen burros. The miners at these workings sack the ore in 70-pound sacks. Three sacks are usually loaded on a burro on regular pack saddles. The distances this ore is packed are not great, seldom over a few hundred feet in a straight line, but the drop is often two or three hundred feet. The burro man is paid a flat rate of 5 or 6 cents per sack, regardless of the amounts or distances packed, except in rare special cases.

Trucking from the mine to the mill is contracted to one man who operates two 1-ton, dump-body, automobile trucks and has a third truck in reserve. The average load of ore is very close to 5,000 pounds. In spite of their overloading, the trucks have stood up well and during their two years of operation the repair cost has not been excessive. The average distance hauled is 1.2 miles, with a drop of 600 feet in that distance. Some short grades are as steep as 18-per cent.

At the mine the stope ore is loaded into the trucks from chutes. The ore is fine and soft and runs freely. Some ore from development work is placed in flat, shallow bins beside the truck road, from which the truck driver shovels it into the truck. This is a small part of the total and the contractor is not paid higher rates for it. At the mill, the ore is weighed by the driver on wagon scales and dumped into a 12-ton hopper over the coarse crusher; if the crusher bin is full, the ore may have to be shoveled by hand into a 300-ton storage bin. The chief costs are gasoline, oil, and tires. The contract rate is $0.75 per ton, or $0.90 if the driver has to shovel into the mill bin. This hauling was formerly done with horses and wagons, at 90 cents per ton, and the contractor just made wages and expenses, whereas at present he is making a fair profit on his investment. Moreover, the tight steel truck bodies have eliminated the appreciable loss which formerly resulted from ore rolling off or sifting through the wagon bodies. The trucking contractor also hauls all mine supplies to the mine at a flat monthly rate.

Estimates have been made for a tramway which showed that the present costs could not be lowered on the present scale of operations. If a larger tonnage were handled and if the ore could be collected at the upper end without too much handling, a tramway might be economical. A tramway would also involve changes in methods of control, and in the recording of grades and amounts of contract ore, with probable greater expense for this supervision

WAGE AND CONTRACT SYSTEM

The labor is about 85 per cent native-born Spanish-American and the turnover is very small. At the start of mining operations, all work was on a day's pay basis. The rates were $4.50 for miners, $4.00 for muckers and $5.50 for blacksmiths. These rates have remained unchanged up to the present, but the amount of work done in the mine on day wage is now not over 5 per cent of the total labor, including supervision. In addition to the mine foreman there are two compressormen-blacksmiths, one carpenter-powderman, and one extra man who serves as roustabout and substitute miner - a total of five men per day on company time.

Contracting was first applied to development work. Development contracts include drilling and breaking, mucking, tramming, and installing track and pipe. The contractor furnishes the labor and explosives, including fuse and caps. The company supplies all equipment and other material. Timbering drifts is paid for extra, by the set.

Stope contracting was begun about a year after mining started. It was first put on the basis of pounds of molybdenum sulphide produced. A contract price of 5 cents per pound was paid. The experiment was tried on only one stope and soon proved the method wrong. The natural tendency of the men was to concentrate on high grade ore to the detriment of complete extraction and eventual stoping efficiency. Moreover, it was very difficult to control. The method then tried, which has continued to the present, was to contract stoping on a tonnage basis. The contractors furnish their own powder, and drill, break, sort, shovel, tram, and load the ore into the trucking bins. The mine foreman exercises close control over mining and sorting to insure complete extraction and proper mill feed. The miners are forced to extract ore from the thin spots, or pinches, as well as the swells. The price is such as to enable them to do this, otherwise the use of stoping as a form of exploration would be impossible. Their contract also includes doing all stope timbering and filling.

All contracts are verbal only and are for indefinite periods and amounts of work. Depending on the men available and their desires, the contract may include one or two men of a crew. A drift contract usually includes only the miner. The mucker in that event is paid by the contractor through the company and at company rates; the company does not concern itself with bonuses or payments to contractors' men at rates over the base rates. If the company furnishes a man to the contractor for a few shifts, the man's wages are deducted from contract payments. Ore produced by development contractors is paid for at te rate of $1 per car. In stopes, two men will often comprise a crew, both being contractors on an equal basis. Additional men may be employed by stope contractors.

Contract rates are very seldom changed, as this increases the confidence of the men in their being allowed to make good profits, and their work is therefore more efficient.

Contract Rates

Drifting, machine work	$ 4.00 to 5.00 per foot
Drifting, hand work	5.00 to 5.50 per foot
Raising, machine work	[1]$ 4.00 per foot
Raising, hand work	[1] 5.00 per foot
Timbering, drift	2.00 per set
Ore, development	[2] 1.00 per car
Ore, stoping, hand work	[2] 3.00 per car
Ore, stoping, machine work	[2] 2.50 per car

1 Timbered raise prices are split, part for advance and part for timbering.

2 Cars of ore are figures from truckload weights on the basis of 1,200 pounds per car.

Contractors handle their own supplies from the surface into the mine.

The powderman keeps tally of powder, fuse, and caps issued. The powderman also acts as mine carpenter and frames all standard timber for drift and raise sets. The miners cut their own stulls.

The mine foreman is in direct charge of the men without assistance. The contract system relieves him of the responsigility of forcing production, but at the same time increases his difficulty in maintaining grade and securing complete and orderly extraction.

SAFETY, DRAINAGE, AND VENTILATION

The mine foreman is responsible for accident prevention and administering first aid; a very good accident record has been established. Falling rocks are the cause of the most serious accidents, therefore emphasis is placed on the necessity for barring down and timbering. The nearest hospitals are at Raton, N. Mex., and at Alamosa, Colo. Doctors are available at several towns within a few miles.

The mine makes little water; drainage is by gravity flow out of the adits.

Ventilation is natural and is assisted by raises from level to level at necessary points. In winter, doors are used to check the too strong currents of cold air.

Table 1.- Development costs per foot, by machine drilling June to November (inclusive), 1930

Description: 2,602 feet drifting, 4½ by 6½ in section, 10 to 20 per cent timbered; 475 feet of raising, 5 by 5 or 5 by 10 section, stulled, raw, or cribbed. Total 3,077 feet. Soft ground, but solid.

	Labor	Material	Total
Drilling	$1.00	-	$1.00
Mucking and tramming (including track and pipe)	1.75	-	1.75
Timbering	.16	$0.14	.30
Explosives (including fuse, caps)	-	1.25	1.25
Rails	-	.22	.22
Ties	-	.08	.07
Pipe	-	.23	.23
Drill repair, hose, oil	.05	.35	.40
Steel sharpening	.23	.10	.33
Compressed air	.32	.65	.97
Supervision	.28	-	.28
Total	$3.79	$3.02	$6.81
Compressor and drills, interest and depreciation			.60
			$7.41

Tagle 2.- Development costs per foot, by hand drilling
June to November (inclusive), 1930

Description: 959 feet drift; 477 feet raising; total 1,436 feet. Same description as for machine work, but generally softer ground.

	Labor	Material	Total
Drilling	$3.20	-	$3.20
Mucking and tramming	1.60	-	1.60
Explosives	-	$0.70	.70
Track	-	.15	.15
Steel sharpening	.23	-	.23
Supervision	.28	-	.28
Timbering	.16	.14	.30
Total	$5.47	$0.99	$6.46

Table 3.- Mining and development costs per ton[1]

Period	1929	1930 (first 10 months)	1929 and 1930 (22 months)
Tonnage	7,846.5	10,112.3	17,958.8
Development, cost per ton[2]	$ 7.48	$ 5.03	$ 6.10
Mining, cost per ton[2]	$ 5.22	$ 5.74	$ 5.51
Total, cost per ton	$12.70	$10.77	$11.61
Labor, cost per ton	$ 9.78	$ 8.34	$ 8.98
Material, cost per ton	$ 2.92	$ 2.43	$ 2.63
Labor, per cent of total cost	76.9	77.4	77.3
Tons per man shift	.551	.626	.591
Feet of development work per ton	1.05	.71	.86

[1] These costs include supervision, and surface expense directly chargeable to mining.

[2] The split between mining and development is estimated.

Table 4.- Mining costs in units of labor, supplies, and power,
June to November (inclusive), 1930. 6,169 tons

Labor, all mine underground and surface, excluding office	1.47 shifts (8-hour) per ton
Supervision	.05 shifts (8-hour) per ton
Explosives, 40 per cent strength gelatin	2.98 pounds per ton
Power for compressed air	16.9 kw. h. per ton
Timber (average 5-inch round)	4.86 linear feet per ton

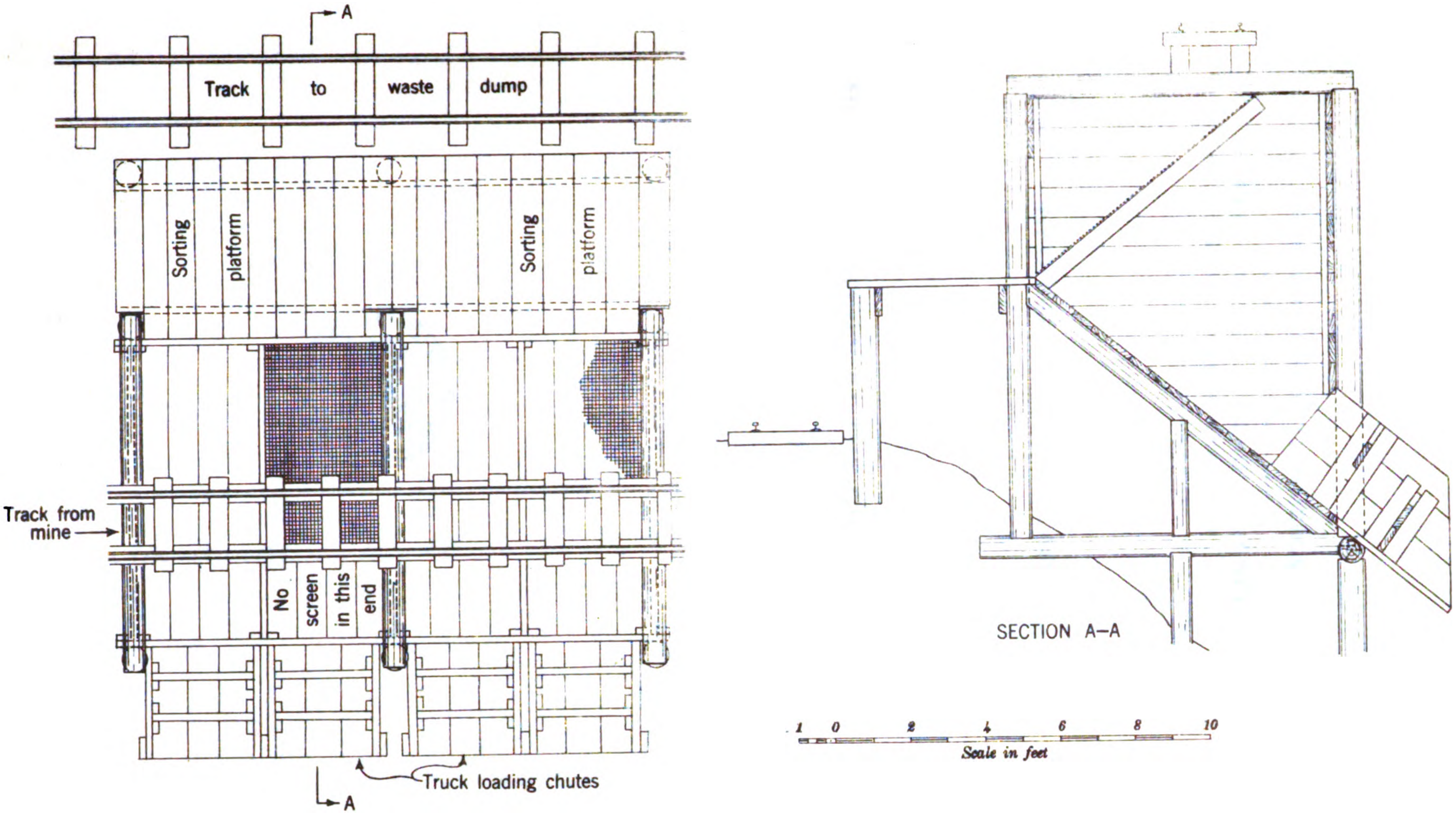

Figure 5.– Typical ore bin, with sorting platform